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**Sheet 2 of the certificate**  
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Koninklijke Philips Electronics N.V.  
5621 BA Eindhoven  
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Arrangement of a chemical-mechanical polishing tool and method of chemical-mechanical polishing using such a chemical-mechanical polishing tool

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Arrangement of a chemical-mechanical polishing tool and method of chemical-mechanical polishing using such a chemical-mechanical polishing tool

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The present invention relates to an arrangement and a method as defined in the outset of claim 1.

5 In the semiconductor industry the Damascene process is widely accepted as the mainstream technology for copper-based interconnect. In the Damascene process, as known to persons skilled in the art, at first a blanket metal (copper) layer is deposited on top of a patterned dielectric layer with sufficient coverage to fill recessed areas in the dielectric layer like trenches and vias. Subsequently, chemical-mechanical polishing (CMP) is used to  
10 remove the metal layer from the surface while the metal in the recessed areas is left behind to constitute (part of) the interconnect pattern.

Conventional CMP processes for metal layers use a slurry, containing basically three components: abrasive particles (e.g.  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ), an etching agent (e.g. an acid) and a passivating agent. The passivating agent passivates the metal's surface by  
15 growing a passivation layer. The abrasive component mechanically removes the passivation layer from the metal. The etching agent is used to etch the unpassivated metal. In the conventional process the three components are dispensed on the polishing cloth as a mixture. Disadvantageously, slurries used in the conventional CMP process are known to have a relatively short period of stability (i.e. the chemical components decompose over time).

20 From US 5,478,435, a dispensing apparatus to dispense a slurry in a CMP apparatus, is known, which dispenses the separate components of the slurry through two (or in some cases, three or more) dispensing tubes to a polishing pad. By keeping the slurry components separated until used at the polishing pad, the dispensing apparatus of US 5,478,435 reduces the problem of the slurry stability. The dispensing tubes transport the  
25 separate components to a point of use on the polishing pad, where the nozzles of the dispensing tubes are located closely together. Thus at the point of use, or proximate to it, the mixing of the components occurs to form the CMP slurry. In an alternative embodiment, the dispensing tubes are interconnected at their end as a single nozzle, located closely to the point

of use. In this single nozzle the mixing of the components then takes place, just prior before reaching the point of use.

From US 5,981,394 a dispensing apparatus is known which also utilizes two separate dispensing tubes to dispense the components of a slurry for mixing at, or close to, the point of use on the polish pad. Here, the second dispensing tube is arranged to supply additional chemical components to the slurry, dispensed by the first tube, for improvement of the CMP process to form a protective surfactant on the metal's surface.

Another disadvantage of CMP processes is the handling of the slurry particles in the system, which cause a poor cleanliness of processed wafers, and which, for example, may also cause damage to pumps and obstruction of waste pipes. Therefore, new slurry-free CMP processes have been developed, in which the abrasive particles in the slurry have been replaced by a fixed-abrasive pad in which the abrasive particles are embedded. Thus, a simple and clean CMP process can be expected, in which only a polishing liquid has to be added to the pad. For example, such a slurry-free CMP process for Cu interconnect is known from an article by M. Matsumoto et al., "Evaluation of Cu CMP for Interconnects Using a New Slurry-Free Process", proceedings of the 1999 Chemical-mechanical polishing for ULSI multilevel interconnection conference CMP-MIC 1999, February 1999, Santa Clara, pp. 176-183.

For the reason of physical and/or chemical stability, the compound ratio of such slurries and the temperature for conventional CMP processes must be within certain limits, which may compromise the performance of such CMP processes in some way. During a CMP process, simultaneously three competing processes (i.e. passivation, abrasion and etching) are taking place on a wafer's surface. Due to the imposed compound ratio, the relative influence of each of the processes is difficult to control. Therefore, a CMP process may not yield optimal results with regard to the dependence on e.g. pattern density, feature size, and uniformity.

Further, an important issue in CMP processing relates to the CMP metal removal rate which is found to depend on the pattern density of the Damascene structure. As known in the art, the large features in a pattern tend to become overpolished in comparison to the smaller features, and dishing effects tend to increase.

Moreover, another problem observed in CMP processing is the removal of abraded materials, which accumulate on the pad. Without removal of the abraded materials from the polishing pad, the abrasive action of the pad will be reduced, and the material removal rate of the CMP process will decrease substantially. As known to persons skilled in

the art, polishing pads can be regenerated by ex-situ cleaning with a brush. However, this procedure reduces the life-time of the polishing pad substantially, due to high wear.

5 It is an object of the present invention to provide an arrangement of a CMP tool and a method to improve CMP processes using such a CMP tool.

The present invention relates to an arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer, comprising a polishing pad, a drive unit, pressing means, a wafer holder, first dispensing means and second  
10 dispensing means; the wafer holder for holding a wafer, being arranged at a holder location; the pressing means being arranged to press the wafer holder to the polishing pad; the first dispensing means for dispensing a first fluid on the polishing pad, being arranged at a first dispensing means location; the second dispensing means for dispensing a second fluid on the polishing pad, being arranged at a second dispensing means location;  
15 the polishing pad comprising a polishing surface for polishing the wafer, and the polishing pad further being connected to the drive unit for moving the polishing surface in a first direction relative to the holder location; characterized in that the first dispensing means location of the first dispensing means is arranged in a downstream direction of the holder location at a first downstream distance, with the downstream direction being taken in relation  
20 to the first direction;  
the second dispensing means location of the second dispensing means is arranged in an upstream direction of the holder location at a first upstream distance, with the upstream direction being taken in relation to the first direction.

Also, the present invention relates to an arrangement of a chemical-mechanical  
25 polishing tool for chemical-mechanical polishing a surface on a wafer, as described above, characterized in that at the first dispensing means location the first dispensing means dispenses an etching agent on the polishing pad for dissolving abraded materials, originating from the surface on the wafer, from the polishing surface of the polishing pad, and at the second dispensing means location the second dispensing means dispenses a mixture of  
30 abrasive particles and a passivating agent on the polishing pad for passivating the surface on the wafer.

Moreover, the present invention relates to a method to be carried out in an arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer, comprising a polishing pad, a drive unit, pressing means, a wafer holder,

first dispensing means and second dispensing means, the wafer holder for holding a wafer, being arranged at a holder location; the pressing means being arranged to press the wafer holder to the polishing pad; the first dispensing means for dispensing a first fluid on the polishing pad, being arranged at a first dispensing means location; the second dispensing means for dispensing a second fluid on the polishing pad, being arranged at a second dispensing means location;

the polishing pad, comprising a polishing surface for polishing the wafer, and the polishing pad further being connected to the drive unit for moving the polishing surface in a first direction relative to the holder location;

10 characterized by the following steps:

- to arrange the first dispensing means location of the first dispensing means in a downstream direction of the holder location at a first downstream distance, with the downstream direction being taken in relation to the first direction, and
- to arrange the second dispensing means location of the second dispensing means in an upstream direction of the holder location at a first upstream distance, with the upstream direction being taken in relation to the first direction.

Also, the present invention relates to a method to be carried out in an arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer, as described above, characterized by the following steps:

- to dispense at the first dispensing means location by the first dispensing means, an etching agent on the polishing pad for dissolving abraded materials, originating from the metal surface on the wafer, from the polishing surface of the polishing pad, and
- to dispense at the second dispensing means location by the second dispensing means, an passivating agent on the polishing pad for passivating the metal surface on the wafer.

25 Thus, the material removal rate of the CMP process according to the present invention will be more constant than in the prior art. Also, the ratio of etching agent and passivating agent in the polishing liquid can be chosen within wider limits than in the prior art. This will provide a better control of the passivation and etching processes. As a consequence, the removal rate will become more constant: i.e. less dependent on feature size and pattern density, which reduces overpolishing and dishing effects.

Moreover, the removal rate uniformity across a wafer can thus be enhanced.

Also, the wafer-to-wafer reproducibility of the CMP process is improved by the arrangement and method of the present invention.



Furthermore, with the present invention the requirement for mechanical conditioning of polishing pads is strongly reduced. Therefore, the life-time of polishing pads will increase due to the present invention. Also, by means of the present invention, the down-time of a CMP tool, due to the replacement and the conditioning of the polishing pad, will  
5 reduce significantly.

Below, the invention will be explained with reference to some drawings, which are intended for illustration purposes only and not to limit the scope of protection as  
10 defined in the accompanying claims.

Figures 1a and 1b show schematically a cross-sectional view of the surface of a polishing pad, before and after contamination with abraded materials, respectively, according to the prior art;

Figure 2 shows schematically in a first preferred embodiment, an example of a  
15 dispensing apparatus, according to the present invention, arranged in a CMP tool;

Figures 3A – 3D illustrate schematically the successive stages of the CMP process as carried out by using the arrangement and the method of the present invention;

Figures 4a and 4b show diagrammatically exemplary results of an experiment, in which the step-height reduction was measured as a function of polishing time in a CMP  
20 process, with and without the application of the present invention, respectively.

To improve CMP processes, the present invention provides an arrangement and a method as will be described below. In Figures 1a and 1b, a cross-sectional view of the  
25 surface of a polishing pad from the prior art is schematically shown. Figure 1a depicts the surface of a clean polishing pad, while in Figure 1b the surface of a polishing pad, contaminated with abraded materials, is shown.

In Figure 1a, a cross-sectional view of a polishing pad's surface 1 comprising a plurality of abrasive particles (diameter:  $\sim 0.1 \mu\text{m}$ ) embedded in the surface of the pad is  
30 schematically shown. The polishing pad consists of a polymer layer, with a slightly undulating surface with hillocks (width:  $\sim 10 \mu\text{m}$ ). When passing under the wafer during CMP, the abrasive particles, depicted here as solid dots, become partially embedded and fixated in the polymer layer

As known to persons versed in the art, the abrasive action of such a polishing pad is substantially performed by the abrasive particles located on, or near to, the tops of the hillocks, which are in contact with the wafer's surface, when in use.

During CMP processing of a metal layer on a semiconductor substrate, the passivated layer in contact with the protruding abrasive particles in the polishing pad is mechanically removed, and deposited on the surface of the pad. The abraded materials accumulate on the surface of the pad as is schematically depicted in Figure 1b by the grey areas at the pad's surface. Due to the accumulation of abraded materials on the pad (and more particularly, at the hillock tops), the abrasive action of the polishing pad diminishes.

The present invention provides an arrangement and a method to prevent the contamination of the pad's surface. As known in the art, mechanical removal of the abraded materials is not very effective and may produce free particles that contaminate a wafer surface.

Therefore, chemical removal by dissolution of the abraded materials is used. Typically, to this end an (acidic) etching agent must be used. However, as known from the prior art, a polishing liquid must not predominantly have the characteristics of such an etching agent, because in that case, the copper layer on the wafer will be etched isotropically without any planarization. As known to persons skilled in the art, severe etching of the metal structure on the wafer surface will then be the result.

In the present invention, the problems of the prior art as mentioned above are solved by an arrangement as shown in Figure 2. Figure 2 shows schematically in a first preferred embodiment, an example of a dispensing apparatus, according to the present invention, arranged in a CMP tool. The CMP tool 3 comprises a polishing pad 4, a wafer holder 5, pressing means 6, an etching agent dispensing tube 7, an passivating agent dispensing tube 8 and a drive unit 9.

The polishing pad 4 is a pad, with a structure as shown in Figure 1a. The polishing pad 4 is provided with the rotational drive unit 9 for rotation while polishing. The polishing pad 4 spins around a centre of rotation R. The rotational direction is indicated by the arrow  $\omega_1$ . At a holder location L0, located at a radial distance from the centre of rotation R, the wafer holder 5 is arranged to hold a wafer W during the polishing process. Connected to the wafer holder 5 is the pressing means 6. During the polishing process the pressing means 6 presses the wafer W in the wafer holder 5 with a predetermined force F to the surface of the polishing pad 4. The pressing means 6 is arranged with a rotational drive unit 9 to rotate the wafer holder 5 during polishing. The rotational direction is indicated by the

arrow  $\omega_2$ . The dispensing apparatus of the CMP tool 3 comprises two dispensing tubes 7, 8 for dispensing the separate components of the polishing liquid to the polishing pad 4. The etching agent dispensing tube 7 dispenses the etching agent on the polishing pad 4 at a first tube location L1. The first tube location L1 is located near the holder location L0, displaced over a first downstream distance d1 in the downstream direction relative to the rotational direction indicated by arrow  $\omega_1$ . The etching agent contains a chemical compound, capable of dissolving the abraded materials, accumulated on the pad's surface, as described with reference to Figure 1b. The passivating agent dispensing tube 8 dispenses a mixture consisting of a passivating agent and abrasive particles, on the polishing pad 4 at a second tube location L2. The second tube location L2 is located near the holder location L0, displaced in the upstream direction over a first upstream distance d3, relative to the rotational direction indicated by arrow  $\omega_1$ . The first upstream distance d3 is equivalent to a second downstream distance d2 measured in the downstream direction, since the movement of a location on the polishing pad describes a closed loop. In the present invention, the first upstream distance d3 to locate the second tube location L2 is chosen in such a way that the second downstream distance d2 is larger than the first downstream distance d1. By positioning the dispensing tubes 7, 8 in this manner, the trajectory between the first dispensing tube 7 and the second dispensing tube 8 (measured in the rotational direction from the first tube location L1 to the second tube location L2) is much larger than the trajectory between the second tube dispensing tube 8 and the first dispensing tube 7 (measured in the rotational direction from the second tube location L2 to the first tube location L1). In this arrangement, advantageously two ranges are created on the polishing pad, each with a different function in the CMP process, as will be explained below in more detail.

The passivating agent (or passivator) is an agent capable of passivating the metal's surface on the wafer by the formation of a passivation layer that protects the metal's surface from the etching agent. The passivating agent may contain an oxidizing agent (e.g.  $H_2O_2$ ), that forms a metal oxide layer on the metal's surface as a passivation layer. Also, the passivating agent may be a reagent that forms a layer of an insoluble metal salt on the metal's surface (e.g., phthalic acid in case of copper-based metallizations). Also, other passivating agents are conceivable that form monolayer coatings on the surface, or passivating agents with surfactant properties.

In the arrangement, as illustrated by Figure 2, the surface of the polishing pad 4, is exposed to various conditions, during a full revolution of the pad. For example, during one revolution of the pad, a particular location L4 at the pad's surface, first passes under the

passivating agent dispensing tube 8 at the second tube location L2. Here, the surface receives a quantity of passivating agent, mixed with abrasive particles.

Next, the location L4 passes under the wafer W attached to the wafer holder 5 at holder location L0. At this point, the abrasive particles embedded in the surface of the polishing pad, remove the passivation layer from the metal surface of the wafer W. The passivating agent dispersed on the pad's surface at location L4, is now in close contact with the metal and passivates the metal's surface again. The abraded materials are deposited on the pad's surface and accumulate on the pad (Figure 1b). At the contact area of the wafer and the polishing pad, the processes of passivation and removal are taking place simultaneously and continuously. It is noted, that due to the presence of etching agent on the pad, after removal of the passivation layer, some etching of the metal layer may occur.

Also, in the present invention, a small quantity of etching agent can be added to the mixture (of passivator and abrasive particles) dispensed at the passivating agent dispensing tube. In this manner, a further control of the characteristics of the CMP process is provided.

Due to the rotation of the polishing pad 4, the abraded materials are transported out of the contact area between the wafer and the polishing pad at the holder location L0.

Subsequently, the location L4 passes under the etching agent dispensing tube 7 at the first tube location L1. The surface receives a quantity of etching agent at this point. The etching agent is capable of dissolving the abraded materials by a chemical reaction. Due to the centrifugal force the solution containing the dissolved abraded materials flows from the pad at the pad's circumference. Therefore, after the dissolution step, the pad's surface is clean and substantially free of abraded materials.

Due to the separated supply of the etching agent and the passivating agent through the etching agent dispensing tube 7 at the first tube location L1 and the passivating agent dispensing tube 8 at the second tube location L2, respectively, the concentration of the etching agent and the passivating agent vary as a function of the relative location on the polishing pad, in relation to the holder location L0. On the trajectory of the location L4 on the pad between the first and second tube locations L1 and L2 of the dispensing tubes 7 and 8, respectively, the concentration of the etching agent on the pad's surface is relatively high in comparison to the concentration of the passivating agent, and the polishing liquid predominantly has the characteristics of an etchant. However, on the trajectory of the location L4 on the pad, between the second and first tube locations L2 and L1, the situation is

reversed: the concentration of the etching agent on the pad's surface is relatively low in comparison to the concentration of the passivating agent, and the polishing liquid predominantly has the characteristics of a passivator. Consequently, the wafer W attached to the wafer holder 5, at the fixed holder position L0 in between the first and second tube locations L1 and L2, is exposed to the polishing liquid with predominantly the characteristics of a passivator. Since the etching agent is still available (in a controllable and relatively low concentration) between the locations L1 and L2, the etching step of the CMP process may be carried out as well at the surface of wafer W. The etch rate is however low, due to the higher concentration of the passivating agent and the corresponding degree of passivation of the surface of the wafer W. It is noted that although the etch rate is low, the removal rate of the CMP process is not affected here. In a CMP process according to the present invention for copper metallization, the removal rate is between 300 and 500 nm/min.

Furthermore, it is noted here that the dispensing of the etching agent and the passivating agent is continuous during the CMP process. Thus, during the CMP process, the concentration distribution of etchant and passivator on the pad can be regarded as a steady-state condition. The rotating polishing pad 4 comprises a first steady-state zone in the trajectory between locations L1 and L2, in which the area of the pad within that first zone is mainly subjected to the etching and cleaning step. In a second steady-state zone in the trajectory between locations L2 and L1, the area of the pad within that second zone mainly contains the passivator, which reacts with the metal's surface on the wafer W.

Also, it is noted that the dispensing of the etching agent and the passivating agent by dispensing tubes 7, 8, may be done in an alternative manner: the tubes 7, 8 may each be arranged in any other suitable shape, e.g. as a shower head assembly with an array of closely spaced openings.

In the embodiment as shown in Figure 2, essential parameters like the flow, the concentration, and the temperature of the etching agent and the passivating agent, respectively, can each be controlled independently, which in the present invention allows a process window which may be wider than for the conventional CMP process.

Figures 3A-3D illustrate schematically in a block diagram the successive stages of the slurry-free CMP process according to the present invention. In the left-hand column, the successive stages of a wafer W schematically depicted in a cross-sectional view, are shown. In the right-hand column, the successive stages of a part of the polishing pad's surface at location L4 are shown schematically in a cross-sectional view.

Figure 3A shows the wafer W prior to the CMP process. Prior to the CMP process, the wafer W comprises a substrate layer 301, an insulating layer 302, and a metal layer 303. In the insulating layer 302 a patterned area 304 is present, which is filled by the metal layer 303. In the surface of the metal layer, a recessed area 305 is shown contouring the patterned area 304.

Figures 3B-3D show the CMP process carried out. In Figure 3B the wafer W is shown with a passivated (metal oxide or metal salt) layer 306 grown by the reaction of the metal with the passivating agent. During polishing, the passivated layer at the top level 307, is removed, while the passivated layer in the recessed area 305 remains on the surface.

This situation is shown in Figure 3C: on the wafer W a protruding area of the free metal surface 308 is present, where the passivated layer is removed.

During the CMP process, the polishing pad 4 appears at the location L2 in a fresh and clean state with abrasive particles embedded in the surface, identical to the situation sketched in Figure 1a. After passing the wafer at holder location L0, the location L4 of the pad arrives at location L1. Due to the accumulation of abraded materials on the polishing pad's surface, the abrasive function of the polishing pad is reduced. At this point L1, the location L4 on the polishing pad 4 is in a state as illustrated in Figure 1b.

At location L1, the etching agent is added to the pad's surface. The polishing fluid at this point has a relatively high concentration of etching agent. During the transfer from location L1 to location L2, the abraded materials are dissolved by the etching agent. Due to the centrifugal force, the solution containing the dissolved abraded materials flows from the pad at the pad's circumference during the transfer from location L1 to L2. The polishing pad 4 now appears fresh before the holder location L0 with the wafer W is reached (again as shown in Figure 1a).

At location L2 a mixture of passivating agent and abrasive particles is dispensed on the pad.

During the CMP process the metal layer is removed until the situation shown in Figure 3D is reached. In Figure 3D, the remaining metal layer is only present in the patterned area as an interconnect 309. Further, at this stage the polishing pad 4 is still clean due to the exposure of the pad to the etching agent between locations L1 and L2 (as shown by the cross-sectional view of Figure 1a).

Due to the constant cleaning of the polishing pad 4 during the CMP process, the material removal rate remains at a constant and high level.

To characterize the CMP process, experiments were carried out using a state-of-the-art polishing tool. As an etching agent a home-made acidic buffer (pH=3) was used. As an passivating agent  $H_2O_2$  (as oxidizer, 35% in  $H_2O$ ) was used. It is noted that the concentration of the etching agent and the passivating agent are given here as examples.

- 5 Other agents and/or concentrations may yield similar satisfactory results.

Wafers, both blanket and patterned (in  $SiO_2$ ), covered by a copper layer with an as-deposited thickness of  $1.2\ \mu m$  were polished by the CMP process according to the present invention. The test Damascene structures on the patterned wafers had various line widths and various pattern densities. As test patterns, line / space patterns, with line widths  
10 from  $0.2$  to  $100\ \mu m$  were used. The pattern density varied from  $\sim 25\%$  to  $\sim 80\%$ . In all test structures, the depth of trenches was  $600\ nm$ .

Figures 4a and 4b show diagrammatically exemplary results of the experiments described above, in which the planarisation rate was measured in a slurry-free CMP process, carried out according to the conventional process as known from the prior art,  
15 and carried out according to the present invention, respectively. In the graph of Figure 4a, the step-height reduction of trenches with various line widths is plotted as a function of the polishing time in a CMP process from the prior art. For clarity, only the results for a pattern density of  $50\%$  are shown. Results on lines with a line width of  $100$ ,  $50$ ,  $20$  and  $10\ \mu m$  are marked by solid circles, open circles, solid triangles and open triangles, respectively. (For  
20 other pattern densities varying from  $\sim 25\%$  to  $\sim 80\%$ , similar results were obtained.)

In the graph of Figure 4b, the step-height reduction of trenches with various line widths is plotted as a function of the polishing time in a CMP process according to the present invention. Results on lines with a line width of  $100$ ,  $50$ ,  $20$  and  $10\ \mu m$  are marked here by solid squares, open squares, solid diamonds and open diamonds, respectively. Again,  
25 the pattern density was  $50\ %$ .

From Figures 4a and 4b it is clear that the CMP process according to the present invention has a higher planarization rate than the conventional CMP process. (Depending on the polishing conditions, the removal rate was in the range from  $300$  to  $500\ nm/min$  for the CMP process according to the present invention.) Also, the step-height  
30 reduction for the CMP process according to the present invention is almost identical for the various line widths of the pattern. Thus, the planarization rate for the CMP process according to the present invention, appears to be (almost) independent from the actual pattern line widths. This indicates clearly that the CMP process according to the present invention reduces the dishing of wider trenches during overpolishing. Due to the higher concentration

of passivating agent on the polishing pad, close to the location of the wafer W, a well-defined passivation layer is constantly formed at the wafer's surface during the full time-span of the CMP process. As illustrated by Figures 3A1-3C2, the formation of a passivation layer efficiently protects the lower recessed areas 305 of the wafer's surface resulting in only the removal of material at the protruding areas 307, 308 of the surface. Therefore, a high and constant planarisation rate is achieved, with very low dependence on the pattern density and pattern feature size.

In summary, the passivation during CMP is improved, due to the improved control of the dispensing of the passivating agent (and the agent's concentration). The planarization of the Damascene structure is improved, because of the improved passivation of the recessed areas in the wafer's pattern. Moreover, the dependence of the planarization on the pattern density is reduced by the better passivation of recessed areas with different feature size.

It will be appreciated that the present invention is not limited to CMP tools with a rotating polishing pad 4 and pressing means 6 at a fixed position L0. The present invention may be applied in other types of CMP tools as known in the art: e.g. with belt-shape polishing pads or with pressing means moving in relation to the (fixed) polishing pad. Also, the present invention may be applied in CMP tools with a fixed-abrasive pad, in which case no abrasive particles need to be dispensed at the passivating agent dispensing tube.

In the present invention, a novel configuration for CMP processing of metals is disclosed. The dispensing tubes are arranged in such a way that the two main components (etchant and passivator) of the polishing fluid are supplied separately on different areas of the polishing pad's surface. The present invention thus reduces the difficulties of composing a polishing slurry and offers better opportunities for process optimization. The trade-off between the etching and the passivation of the surface is improved by separating the etchant and passivator flows to the polishing pad. The separation of the components results in composition gradients which lead to a different passivation rate of the metal and different dissolution rates of metal oxides (or metal salts) at different areas of the polishing pad's surface. Consequently, the CMP process according to the present invention obtains excellent removal and planarization rates.

Also, it will be appreciated, that in the dispensing of the passivating agent at the passivating agent dispensing tube 8 a small quantity of etching agent may be added controllably to the passivation agent, in order to have some slight etching action simultaneous



with the polishing and the passivation actions, while processing a wafer W at the location L0 of the wafer holder.

Moreover, it will be appreciated that the CMP process according to the present invention is not to be used exclusively for copper-based metallization, but also for other  
5 metallizations. For example, CMP processing according to the present invention, shows good results relating to the patterning of tungsten layers.

Also, the lifetime of the polishing pad increases since the requirements for mechanical conditioning of the pad is strongly reduced by the in-situ cleaning action of the etching agent.

10 It will be evident to those skilled in the art that the arrangement and method of the invention can be advantageously applied in the manufacture of semiconductor devices.

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## CLAIMS:

22 12 2000

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1. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer, comprising a polishing pad (4), a drive unit (9), pressing means (6), a wafer holder (5), first dispensing means (7) and second dispensing means (8); the wafer holder for holding a wafer (W), being arranged at a holder location (L0); the pressing means (6) being arranged to press the wafer holder (5) to the polishing pad (4); the first dispensing means (7) for dispensing a first fluid on the polishing pad (4), being arranged at a first dispensing means location (L1); the second dispensing means (8) for dispensing a second fluid on the polishing pad (4), being arranged at a second dispensing means location (L2);
- 5 the polishing pad (4) comprising a polishing surface for polishing the wafer (W), and the polishing pad (4) further being connected to the drive unit (9) for moving the polishing surface in a first direction ( $\omega_1$ ) relative to the holder location (L0); characterized in that
- 10 the first dispensing means location (L1) of the first dispensing means (7) is arranged in a downstream direction of the holder location (L0) at a first downstream distance (d1), with the downstream direction being taken in relation to the first direction ( $\omega_1$ );
- 15 the second dispensing means location (L2) of the second dispensing means (8) is arranged in an upstream direction of the holder location (L0) at a first upstream distance (d3), with the upstream direction being taken in relation to the first direction ( $\omega_1$ ).
- 20
2. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to claim 1, characterized in that at the first dispensing means location (L1) the first dispensing means (7) dispenses an etching agent on the polishing pad (4) for dissolving abraded materials, originating from the surface
- 25 on the wafer (W), from the polishing surface of the polishing pad (4), and at the second dispensing means location (L2) the second dispensing means (8) dispenses a mixture of abrasive particles and a passivating agent on the polishing pad (4) for passivating the surface on the wafer (W).

3. Arrangement according to any of the preceding claims, characterized in that the dispensing means (7, 8) comprise a dispensing tube.
4. Arrangement according to claim 1 or 2, characterized in that the dispensing means (7, 8) comprise a dispensing tube with a plurality of closely spaced dispensing openings.
5. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any one of claims 1 to 4, characterized in that the surface on the wafer (W) is a surface of a metal layer.
6. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to claim 5, characterized in that the metal layer is a copper layer.
7. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to claim 5, characterized in that the metal layer is a tungsten layer.
8. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any one of claims 5 to 7, characterized in that the passivating agent is an oxidizing agent for the metal layer.
9. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any one of claims 5 to 7, characterized in that the passivating agent is a reagent that forms a layer of an insoluble metal salt on the metal layer.
10. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any one of claims 5 to 7, characterized in that the passivating agent is a reagent that forms a thin film coating on the metal layer, the thin film being a monolayer.

11. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any one of claims 5 to 7, characterized in that the passivating agent is a surfactant.
- 5 12. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to claim 8, characterized in that the oxidizing agent is  $H_2O_2$ .
- 10 13. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to claim 9, characterized in that the passivating agent is phthalic acid.
- 15 14. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any one of claims 5 to 7, characterized in that the etching agent is a dissolving agent for abraded metal / metal-oxide / metal salt materials.
- 20 15. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to claim 14, characterized in that the etching agent is an acidic buffer for dissolving abraded metal / metal-oxide / metal salt materials.
- 25 16. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), further comprising rotational means for rotating the wafer holder (5) according to any one of the preceding claims, characterized in that the wafer holder (5) being connected to the rotational means is being arranged to rotate in second rotational direction ( $\omega_2$ ).
- 30 17. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any one of the preceding claims, characterized in that the polishing surface for polishing the wafer (W) of the polishing pad (4) is being arranged as a fixed abrasive pad, and the second dispensing means (8) dispenses the passivating agent.

18. Arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any one of the preceding claims, characterized in that the second dispensing means (8) also dispenses a small quantity of the etching agent.

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19. A method to be carried out in an arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer, comprising a polishing pad (4), a drive unit (9), pressing means (6), a wafer holder (5), first dispensing means (7) and second dispensing means (8); the wafer holder for holding a wafer (W), being  
10 arranged at a holder location (L0); the pressing means (6) being arranged to press the wafer holder (5) to the polishing pad (4); the first dispensing means (7) for dispensing a first fluid on the polishing pad (4), being arranged at a first dispensing means location (L1); the second dispensing means (8) for dispensing a second fluid on the polishing pad (4), being arranged at a second dispensing means location (L2);

15 the polishing pad (4) comprising a polishing surface for polishing the wafer (W), and the polishing pad (4) further being connected to the drive unit (9) for moving the polishing surface in a first direction ( $\omega_1$ ) relative to the holder location (L0); characterized by the following steps:

- to arrange the first dispensing means location (L1) of the first dispensing means (7) in a  
20 downstream direction of the holder location (L0) at a first downstream distance (d1), with the downstream direction being taken in relation to the first direction ( $\omega_1$ ), and
- to arrange the second dispensing means location (L2) of the second dispensing means (8) in an upstream direction of the holder location (L0) at a first upstream distance (d3), with the upstream direction being taken in relation to the first direction ( $\omega_1$ ).

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20. A method to be carried out in an arrangement of a chemical-mechanical polishing tool (3) for chemical-mechanical polishing a surface on a wafer (W), according to claim 19, characterized in that the surface on the wafer (W) is a surface of a metal layer.

30 21. A method to be carried out in an arrangement of a chemical-mechanical polishing tool (3) for chemical-mechanical polishing a surface on a wafer (W), according to claim 20, characterized by the following steps:

- to dispense at the first dispensing means location (L1) by the first dispensing means, an etching agent on the polishing pad for dissolving abraded materials, originating from the metal surface on the wafer (W), from the polishing surface of the polishing pad, and
- to dispense at the second dispensing means location (L2) by the second dispensing means, an passivating agent on the polishing pad for passivating the metal surface on the wafer (W).

22. A method to be carried out in an arrangement of a chemical-mechanical polishing tool (3) for chemical-mechanical polishing a surface on a wafer (W), according to any one of claims 19 to 21, characterized in that the dispensing means (7, 8) comprise a dispensing tube.

23. A method to be carried out in an arrangement according to any one of claims 19 to 21, characterized in that the dispensing means (7, 8) comprise a dispensing tube with a plurality of closely spaced dispensing openings.

24. A method to be carried out in an arrangement of a chemical-mechanical polishing tool (3) for chemical-mechanical polishing a surface on a wafer (W), according to any one of claims 20 to 23, characterized in that the metal layer is a copper layer.

25. A method to be carried out in an arrangement of a chemical-mechanical polishing tool (3) for chemical-mechanical polishing a surface on a wafer (W), according to any one of claims 20 to 23, characterized in that the metal layer is a tungsten layer.

26. A method to be carried out in an arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any one of claims 20 to 25, characterized in that the passivating agent is an oxidizing agent for the metal layer.

27. A method to be carried out in an arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any one of claims 20 to 25, characterized in that the passivating agent is a reagent that forms a layer of an insoluble metal salt on the metal layer.

28. A method to be carried out in an arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any one of claims 20 to 25, characterized in that the passivating agent is a reagent that forms a thin film coating on the metal layer, the thin film being a monolayer.
- 5
29. A method to be carried out in an arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any one of claims 20 to 25, characterized in that the passivating agent is a surfactant.
- 10
30. A method to be carried out in an arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to claim 26, characterized in that the oxidizing agent is  $H_2O_2$ .
31. A method to be carried out in an arrangement of a chemical-mechanical
- 15 polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to claim 27, characterized in that the passivating agent is phthalic acid.
32. A method to be carried out in arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any one of
- 20 claims 20 to 25, characterized in that the etching agent is a dissolving agent for abraded metal / metal-oxide / metal salt materials.
33. A method to be carried out in arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to claim 32,
- 25 characterized in that the etching agent is an acidic buffer for dissolving abraded metal / metal-oxide / metal salt materials.
34. A method to be carried out in arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), further comprising
- 30 rotational means for rotating the wafer holder (5) according to any one of claims 19 to 33, characterized by the following step:
- to arrange the rotational means to rotate the wafer holder (5) in a second rotational direction ( $\omega_2$ ).



35. A method to be carried out by an arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any one of claims 19 to 34, characterized by the following steps:

- to arrange the polishing surface for polishing the wafer (W) of the polishing pad (4) as a  
5 fixed abrasive pad;
- and to dispense the passivating agent by the second dispensing means (8).

36. A method to be carried out by an arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer (W), according to any  
10 one of claims 19 to 35, characterized by the following step:

- to dispense a small quantity of the etching agent by the second dispensing means (8).

37. A method to be carried out in an arrangement of a chemical-mechanical  
15 polishing tool for chemical-mechanical polishing a surface on a wafer (W) according to any one of claims 19 to 36, characterized in that the chemical-mechanical polishing treatment is used in the manufacture of a semiconductor device, the wafer (W) comprising a substrate of a semiconductor material.

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ABSTRACT:

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The invention relates to an arrangement of a chemical-mechanical polishing tool for chemical-mechanical polishing a surface on a wafer, comprising a polishing pad (4), a drive unit (9), pressing means (6), a wafer holder (5), first dispensing means (7) and second dispensing means (8); the wafer holder for holding a wafer (W), being arranged at a holder location (L0); the pressing means (6) being arranged to press the wafer holder (5) to the polishing pad (4); the first dispensing means (7) for dispensing a first fluid on the polishing pad (4), being arranged at a first dispensing means location (L1); the second dispensing means (8) for dispensing a second fluid on the polishing pad (4), being arranged at a second dispensing means location (L2); the polishing pad (4) comprising a polishing surface for polishing the wafer (W), and the polishing pad (4) further being connected to the drive unit (9) for moving the polishing surface in a first direction ( $\omega_1$ ) relative to the holder location (L0);

wherein the first dispensing means location (L1) of the first dispensing means (7) is arranged in a downstream direction of the holder location (L0) at a first downstream distance (d1), with the downstream direction being taken in relation to the first direction ( $\omega_1$ ); and the second dispensing means location (L2) of the second dispensing means (8) is arranged in an upstream direction of the holder location (L0) at a first upstream distance (d3), with the upstream direction being taken in relation to the first direction ( $\omega_1$ ).

The invention further relates to a method of chemical-mechanical polishing using such an arrangement.

Fig. 2

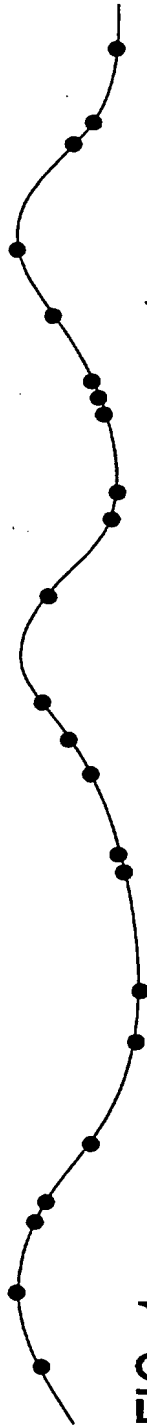
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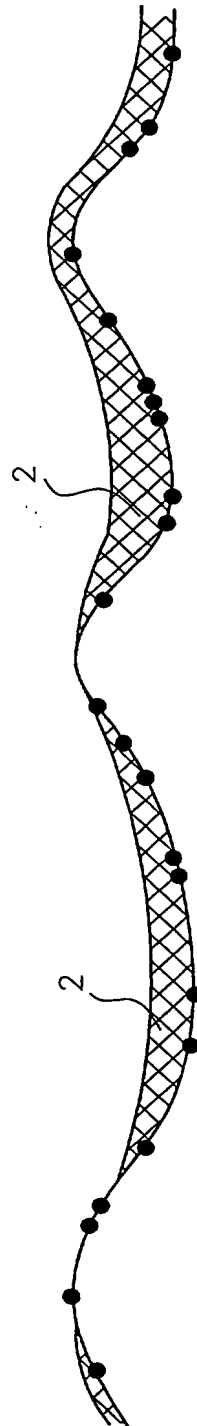
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1/4



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FIG. 1a



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FIG. 1b

2/4

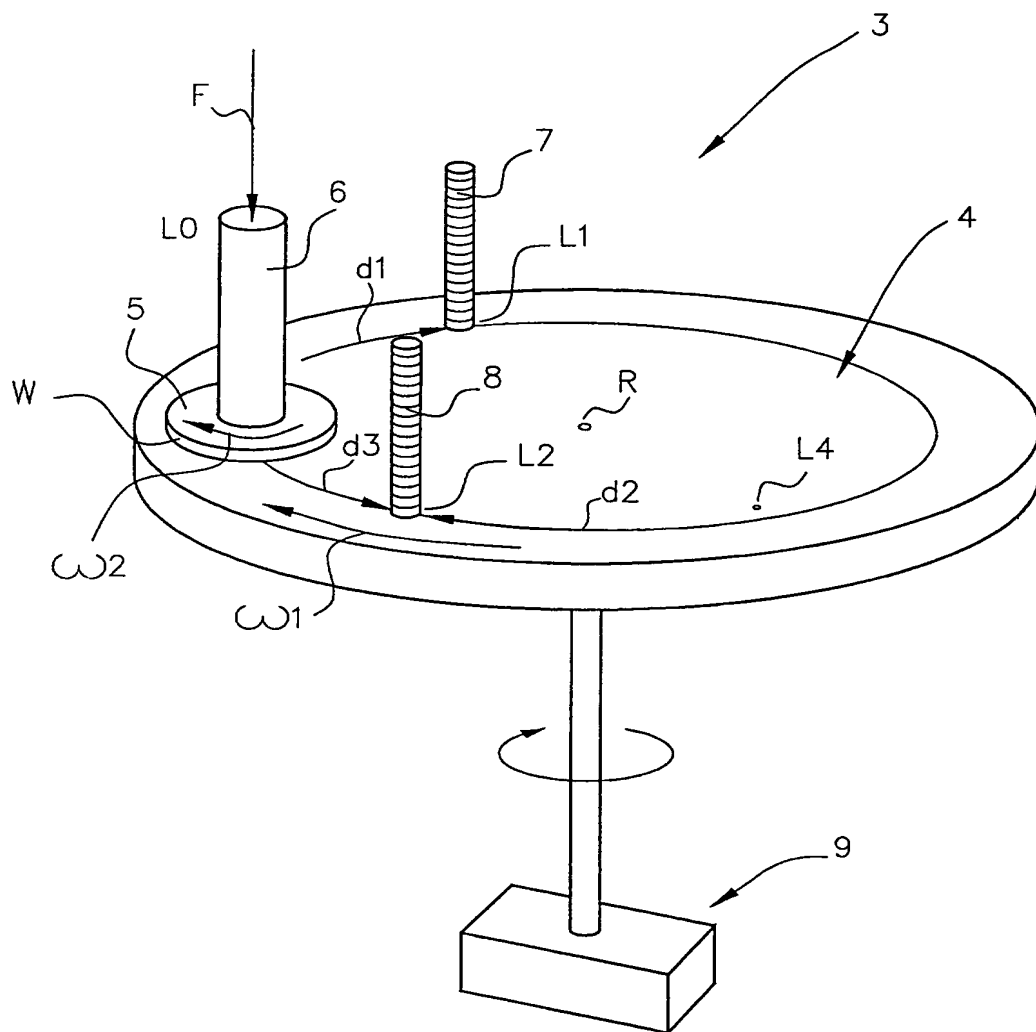


FIG. 2



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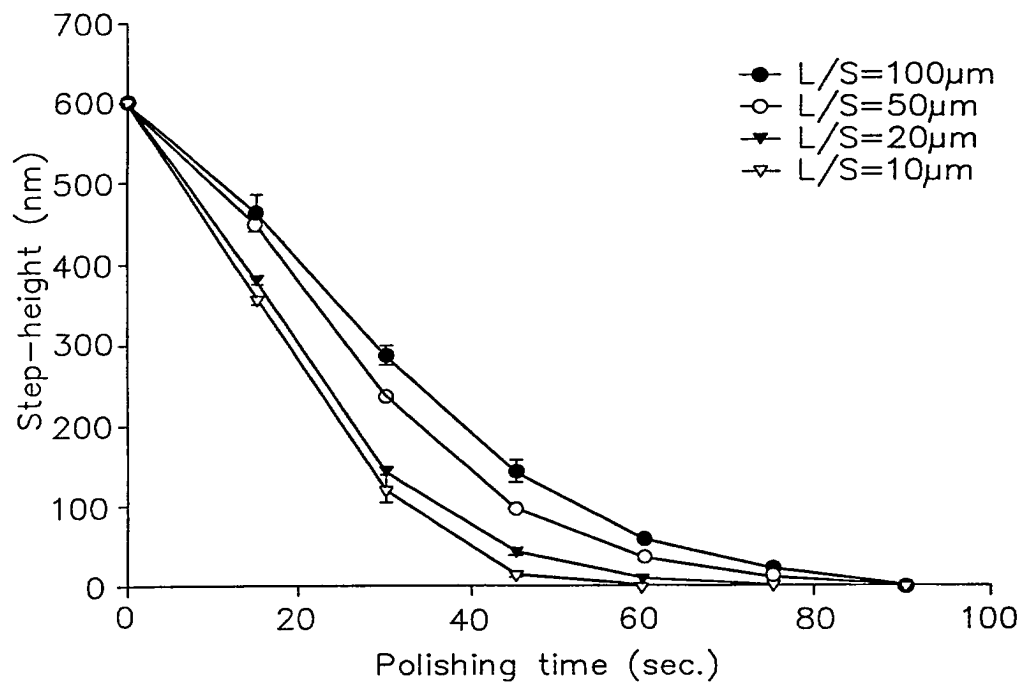


FIG. 4a

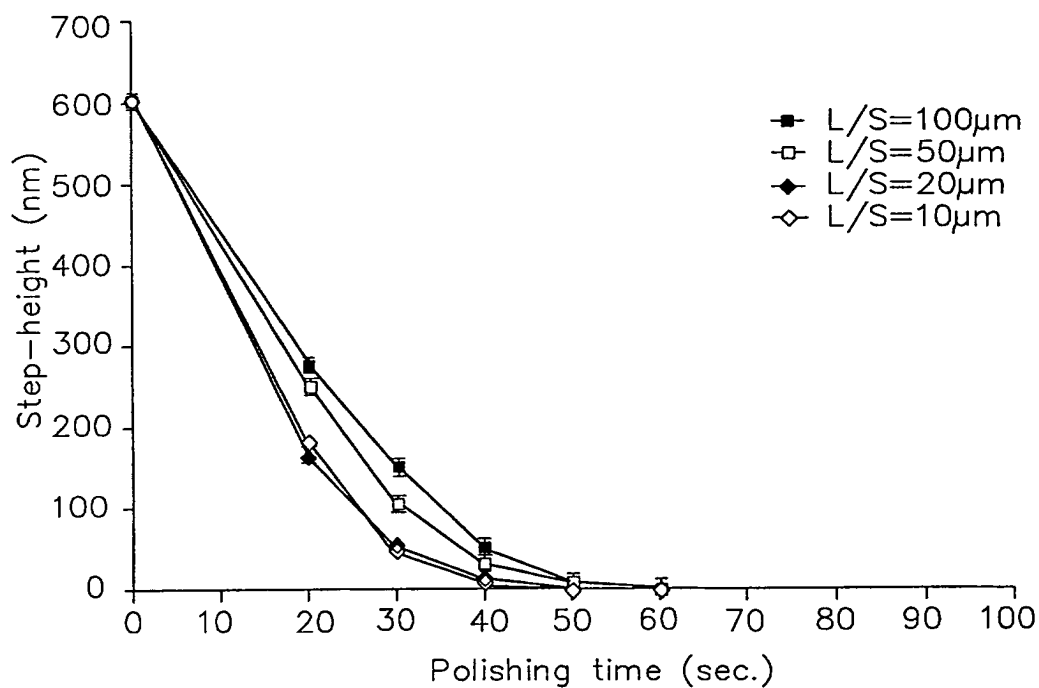


FIG. 4b